First 2-Gbps Observations between the KVAZAR VGOS Antennas and the Yebes RAEGE Antenna

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Abstract A series of joint test observations using three 13-m VGOS antennas was carried out between September and November 2015. These included experiments at two different recording rates: 256 Mbps and, for the first time, 2 Gbps. Two different DBBC2 working setups, Digital Down Conversion and Polyphase Filter Bank, were used at Yebes; the data recorded was e-transferred to the IAA Correlator Center. Combined correlation of mixed bandwidth data from the KVAZAR antennas and Yebes were performed with DiFX 2.4, and some results were obtained.

Keywords VLBI, VGOS, KVAZAR, RAEGE

1 Introduction

A series of eight experiments were carried out with the 13.2-m antenna network of Zelenchukskaya (Zv) and Badary (Bv) in Russia and the 13.2-m antenna at Yebes (Yj) in Spain. All antennas are of ring-focus design and are equipped with an S/X/Ka-receiver. There are differences between the antennas' data acquisition and recording systems: Yebes uses a DBBC2 and a Mark 5B+; Badary and Zelenchukskaya have a BRoadband Acquisition System (BRAS) [5, 6, 7] and a Data Transmitting and Recording System (DTRS) [1]. Observation scheduling, data correlation, and analysis were performed at the IAA in Russia. A short summary of all experiments is presented in Table 1.

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2 Scheduling

Geodetic scheduling was performed with a modified version of the SKED software (version 2007Feb13) [4]. On-source times ranged from 22 to 100 s (RU0179, RU0180, RU0181), 30–100 s (RU0191, RU0192), 90-150 s (RU0222, RU0224), 50–180 s (RU0263), and a target signal-to-noise (SNR) of 20 dB in both X- and S-band. The scan sequence was automatically optimized for UT1-UTC estimation. NRAO SCHED key-files were prepared with the frequency setup, and the scan sequence from the skd-file was added later. Final vex-files were transferred to the stations.

The setup for Badary and Zelenchukskaya included three 512-MHz-wide frequency channels in X-band covering the range between 7568 and 9104 MHz and a single 512-MHz-wide channel in S-band covering the 2164–2676 MHz bandwidth.

For the first experiments, we tested the PFB mode of the DBBC2 at the RAEGYEB station. Frequencies were selected in the second Nyquist zone to cover 512 MHz in X-band and S-band with gaps; in S-band the KVAZAR receivers have filters between 2400–2500 MHz to avoid local RFI (see Table 2). Several scans in DDC mode were added in subsequent experiments to ease diagnostics and the fringe search.

3 Data Correlation

The recorded data were e-transferred to the IAA Correlator Center in St. Petersburg via optical fiber. Correlation was done with DiFX 2.4 [2] on the new blade-server hybrid cluster in the IAA using the *"zoom band"* capability of the software correlator because the

Table 1 Brief summary of the experiments. In RU0191, RU0222, RU0224 several scans at the beginning were recorded in the DDC mode and the rest in the PFB mode. DBBC mode, the number of intermediate frequency bands, their polarizations and bandwidths are specified in the *Frequency setup* column for each station.

Session name	Start date and time, UT	Duration, h	Number of scans	Frequency setup
RU0179	2015-09-09 19:00	1	40	ZvBv: 3X LCP and 1S RCP, 512 MHz Yj:PFB, 8X RCP and 8S LCP, 32 MHz
RU0180	2015-09-10 19:00	1	39	
RU0181	2015-09-11 19:00	1	39	
RU0191	2015-10-14 07:00	1	44	ZvBv: 3X and 1S RCP, 512 MHz Yj:DDC, 8X, RCP, 16 MHz Yj:PFB, 8X and 8S, RCP, 32 MHz
RU0192	2015-10-15 07:00	1	44	ZvBv: 3X and 1S RCP, 512 MHz Yj:DDC, 4X and 4S, RCP, 16 MHz
RU0222	2015-11-09 09:00	3	75	ZvBv: 1X and 1S, RCP, 512 MHz Yj:DDC, 8X, RCP, 16 MHz Yj:PFB, 8X and 8S, RCP, 32 MHz
RU0224	2015-11-10 09:00	3	77	
RU0263	2015-11-20 09:00	4	109	

Table 2 Sky frequency values (MHz) for scheduled experiments.

RU0179	X	9072	9008	8944	8880	8816	8752	8688	8624
RU0180 RU0181	S	2612	2580	2548	2388	2356	2324	2292	2260
RU0191	X	9076	9044	8980	8916	8852	8788	8724	8660
	S	2612	2580	2548	2388	2356	2324	2292	2260
RU0192	X	8964	8948	8932	8916				
	S	2324	2308	2292	2276				
RU0222	X	9076	9044	9012	8980	8948	8916	8884	8852
RU0224 RU0263	S	2612	2580	2548	2388	2356	2324	2292	2260

KVAZAR stations are equipped with BRAS and able to record only 512 MHz-wide frequency channels and Yebes with DBBC2 in DDC mode has 16 MHz-wide channels and in PFB mode 32 MHz per channel. Detailed frequency setups for every experiment are presented in Table 2.

During the experiments, we experienced different kinds of problems: in RU0179, Zelenchukskaya was misconfigured with the wrong VDIF frame size. Additionally, the DBBC2 at Yebes was not properly configured. Thus only RU0180 and RU0181, which yielded fringes for the Bv-Zv baseline, were analyzed for EOPs. RU0191 required corrections to the setup, but only fringes between Badary, Zelenchukskaya, and Yebes in DDC mode were found, whereas the scans in PFB mode at Yebes yielded no fringes. RU0192 was also unsuccessful because data from the KVAZAR stations were lost during transfer. RU0222 and RU0224 were correlated with successful results both in the DDC mode and the PFB mode at Yebes. RU0263 is currently in the correlator queue.

4 Analysis

The *PIMA* software [8] was used for data post-processing and to produce NGS-card files. This includes the resolution of the delay ambiguities and the calculation of the ionospheric contribution. The analysis was done with the *"Quasar"* software suite [3]. All sessions were analyzed, but due to different problems that arose during the sessions, only a few sessions can be considered successful. Pre-fit residuals of the session RU0224 are shown in Figure 1. Yebes shows a linear clock offset. Zelenchukskaya's position was fixed, and the following parameters were estimated: station positions, a linear zenith wet delay, and linear clocks. The corresponding post-fit residuals of the session RU0224 are shown in Figure 2. Root mean square residuals (RMS) are presented in Table 3. The final weighted root mean square residuals (WRMS) are about 49 ps, and the corresponding mean ionospheric free group delay error is about 114 ps. In comparison, the typical WRMS for the 512 MHz-wide bands of the Bv-Zv baseline is below 10 ps.

Table 3 Root-mean-square residuals for the RU0224 experiment.

Baseline	RMS, ps
Badary-Yebes	239
Badary-Zelenchukskaya	67
Yebes-Zelenchukskaya	205
average	138

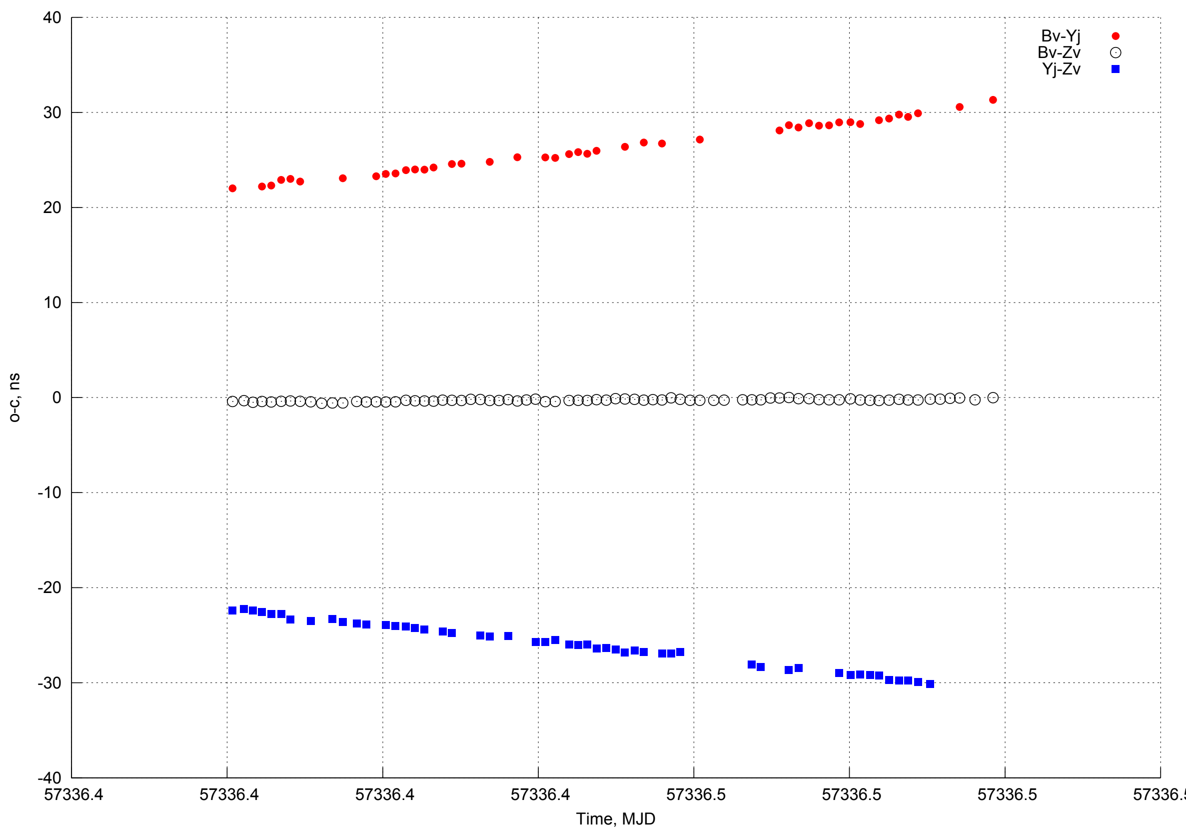

Fig. 1 Pre-fit residuals of the session RU0224 on November 10, 2015.

5 Conclusions

A first analysis of an international Intensive experiment using a VGOS network has been done. The Yebes DBBC2 setup in PFB mode is compatible with KVAZAR's Badary and Zelenchukskaya equipment. The successful combined correlation of KVAZAR stations and RAEGYEB in the PFB mode of the DBBC2 was performed.

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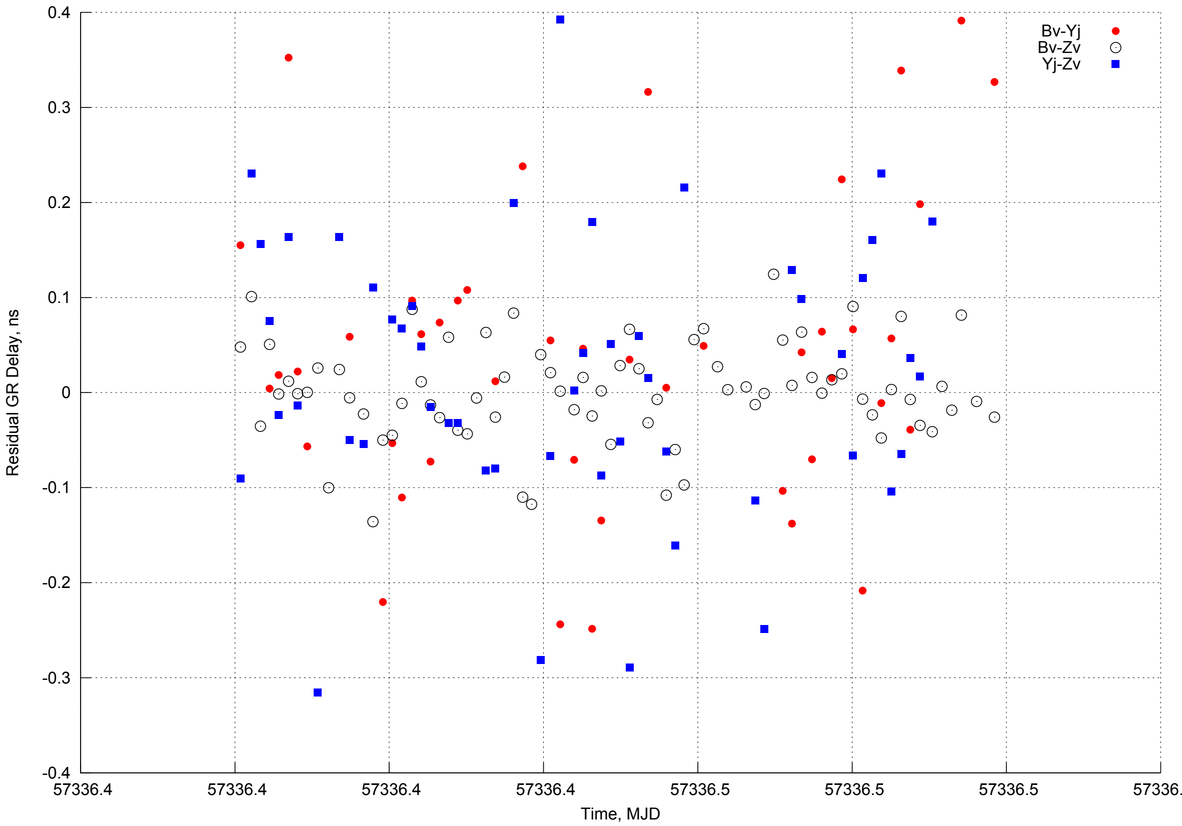

Fig. 2 Post-fit residuals of the session RU0224 on November 10, 2015.

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